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ABSTRACT

This paper discusses various aspects of conceptual change instruction and research related to conceptual change strategies. The role played by teachers in the conceptual change process has been neglected in the research and understanding that role requires that: (1) the Conceptual Change Model of Posner provide a reasonable framework for thinking about change and how the change can be documented; (2) teachers are acquainted with conceptual change research; and (3) the implementation of the principles of conceptual change instruction is seen as a process. In addition to framing the problem, other sections of this paper address thoughts on the conceptual change model, science content, metacognition, and the role of the learner. The conclusions pertain to the social construction of the content and classroom environment, the importance of engaging students in activities designed to elicit metacognitive reflection, and the need for students to accept and assume the role of active learner. Contains 16 references. (DDR)

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CONCEPTUAL CHANGE INSTRUCTION: SOME THEORETICAL AND PEDAGOGICAL ISSUES

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Introduction

Teaching for conceptual understanding of significant science concepts is a universal goal of science instruction. Barriers to achieving this goal occur at many levels both internal and external to classroom experiences of teachers and students. The role of a teacher in implementing instruction that effectively addresses students' conceptual understanding is explored in this paper. At this time, it is widely recognized that students' conceptions of scientific phenomena are frequently in conflict with currently accepted scientific thought and resistant to change even following good instruction. Interest in affecting change in students' conceptions has produced a large body of research documenting the variety of conceptions students hold, curricular efforts intending to address change in students' conceptions, and a theoretical model of conceptual change proposed by Posner, Strike, Hewson & Gertzog (1982). Seldom the focus of research studies in the current literature, the significance of the teacher's role in affecting conceptual change learning would add to the current understanding of students' learning reported in science education literature.

Understanding the role played by teachers who teach for conceptual change requires several caveats. First, it is assumed that the central components of the Conceptual Change Model of Posner et al. (1982) provide a reasonable framework for thinking about what might change in a students' conception and how that change might be documented. This is not to imply that the Conceptual Change Model (hereafter referred to as CCM) provides a complete description of the process of conceptual change, only that the components of the CCM are reasonable constructs, that the components of the CCM could be taught to teachers, and that the validity of the components are testable. Second, it is assumed that teachers are substantially acquainted with current ideas in the field of conceptual change research (i.e., the extent of and variety in students' conceptions in science) and education more broadly (i.e., constructivist views of teaching and learning). This assumption suggests a teacher

actively pursuing professional development in the field of science education, either formally or informally. Finally, it is assumed that implementing the principles of conceptual change instruction described below must be seen as a process and not a heuristic device. Given the consequences of the constructivist view of learning underlying the CCM, it follows that teachers will construct individual views of their roles in implementing conceptual change instruction.

Thoughts About the Conceptual Change Model

The CCM includes two components, status and the conceptual ecology, that are useful in thinking about students' conceptions. The status component can be used to categorize the degree to which a student believes in an expressed conception. Hewson and Thorley (1989) described the utility of the status component in terms of understanding student learning and mechanisms for differentiating status in classroom discourse (Thorley, 1990). The influence of individual components of the conceptual ecology , although not as extensively researched, are also reported in the literature (Hewson, 1985; Beeth, 1993). Familiarity with components of the CCM and, more importantly, the ability to identify them during instruction provide the teacher with an indication of the degree to which a student is committed to a particular conception (i.e., the status of the conception) and the means of justification for that conception represented by components of the conceptual ecology. Hewson and Thorley (1989, 541) recognize the necessity of both components in the following:

> There are two major components to the model of conceptual change, the [status] *conditions* that need to be satisfied in order for a person to experience conceptual change and the person's *conceptual ecology* that provides the context in which the conceptual change occurs and has meaning.

The teacher's ability to identify changes in the status of students' conceptions is crucial to affecting conceptual change learning. Teachers can know the status of a conception only if they actively seek out the kind of information that indicates status. Hennessey

(1991) did this by teaching students to use the status language of the CCM. Other possible methods include individual interviews designed to elicit status (as in the interview with Heather in the Private Universe tape), documenting current ideas and reflective thoughts about previous ideas either verbally, on audio tape or through written assignments (e.g., 'I now think ... but I used to think ... and my idea changed because ...'), and cooperative strategies involving a second teacher/researcher who focuses their attention on identifying references to the status of students' conceptions. The second teacher/researcher would then conference with the primary teacher after class to discuss issues related to students' conceptual understanding. Similar techniques could be used to identify, document, and discuss components of the conceptual ecology expressed or inferred by students. It is critical to point out that teachers may not have easily identifiable student comments to work with and that they will frequently need to infer status or some component of the ecology. The ability to make accurate inferences concerning status and the ecology is recognized as a critical act on the part of the teacher.

Thoughts About Science Content

Teachers also need to consider a number of issues related to their own views of learning and their methods of instruction when teaching for conceptual change. Stofflett (1992) and Stofflett and Stoddart (1994) suggested that pre-service teachers need to experience conceptual change learning themselves before designing conceptual change lessons planned to address their students' conceptual understanding. Results from studies like those identified above are indicative of a need for teachers to know more about conceptual change learning than merely the mechanics of instruction. For example, the initial activity in many documented approaches to conceptual change instruction is the exposure of students' existing thoughts on a topic. However, once students' ideas are exposed there is little indication as to how the teacher might work with those ideas. This paper identifies theoretical components of the Conceptual Change Model (Hewson, 1981; Posner,

Strike, Hewson & Gertzog, 1982) that teachers might consider when attempting to implement principles of conceptual change through their instruction.

A fundamental assumption of conceptual change instruction is that the teacher must know the science content and issues of learning related to the content they are about to teach. Teachers must have a sound understanding of the factual and propositional information related to the science content they choose to teach. In addition they should also have an understanding of which issues were significant in the historical development of the science content. Novice learners frequently express conceptions consistent with earlier versions of a science concept accepted by scientific communities in the past, and frequently for similar reasons. Analyzing students' expressed conceptions in light of historical developments of that conception allow the teacher to categorize the students' conceptions (i.e., as Aristotelian, Darwinian, a force implies a motion, matter is continuous, etc.) and to select instructional activities that address crucial empirical and philosophical aspects related to changes in that conception. The ability of a teacher to focus the attention of learners on critical observations, significant data or philosophical issues related to changes in a conception could provide the dissatisfaction necessary for initiating conceptual change.

Thoughts About Metacognition

However, observing a critical demonstration or event, by itself, is not enough to produce a change in conceptual understanding. Given that a learner finds some event dissatisfying, it is necessary to examine their thinking about this event -- to be metacognitive about the situation. The learner needs to examine what it is they are dissatisfied with, and the status and conceptual ecology components of the Conceptual Change Model (hereafter referred to as CCM) provide a means of thinking about dissatisfaction. It is reasonable to assume that a learner could be dissatisfied with: 1) the event as experienced (i.e., the event represents an anomaly to the way the world works), or 2) their thinking about this experience (i.e., 'the way I am thinking about this phenomena does not match my

experiences with it'). Both characterizations represent anomalies but for different reasons. Anomalies can occur in a world totally external to the learner, as in the first instance above, or internal to the learner's thinking about the event. Metaphysical beliefs expressed by learners about the capability of inanimate objects to produce a force or not produce a force are one example of this distinction. If the learner expressed the view that inanimate objects are incapable of exerting a force, he or she is unwilling to think about solid objects as capable of exerting a force. In this instance the teacher might facilitate learning by a sequence of "bridging analogies" (Brown, 1994; Brown & Clement, 1989), eventually addressing solid objects at the molecular level. Bridging analogies might allow learners to produce a linear causal mechanism (Guitierrez & Ogborn, 1992) that explains how solid objects might produce a force, if they could. While it is necessary for the teacher in instances such as this to present multiple demonstration of inanimate objects exerting forces, it is also necessary for the learner to consider (become dissatisfied with) their metaphysical belief about the nature of inanimate objects.

The example above contains two assumptions about teachers and what they need to know when implementing conceptual change instruction. First, teachers need to understand the role and function of components of a learners conceptual ecology in relation to learning. In the example above, anomalies, metaphysical beliefs, discrepant events, images of real world objects, and exemplars of entire classes of phenomena were part of the learning environment. Any one or all of these can be problematic for the learner, and if so, need to be addressed by the teacher. Brown and Clement's (1989) successful work on the use of bridging analogies to affect conceptual change in a metaphysical belief provides evidence for the role played by this component of the conceptual ecology. The use of discrepant events to confront anomalies between what a learner is thinking and what he or she might think, and the role of images and exemplars identified in Minstrell's teaching (cited in Thorley, 1990) provide additional instances in which components of the conceptual ecology are addressed

during conceptual change instruction. The status component of the conceptual ecology has also been addressed during instruction through modeling by the teacher (ex. "shoot, if I want to think about this as a physicist would ...", taken from Minstrell video tape) and during direct instruction of the language of the CCM (Hennessey, 1991). Second, the teacher needs to be well founded in philosophical issues related to the nature of scientific knowledge. The Conceptual Change Model of Posner et al. (1982, p. 215) suggests "some standards for successful knowledge such as elegance, economy, parsimony, and not being *ad hoc*" as aspects of a learner's epistemology. Therefore learners' thoughts concerning the nature of scientific knowledge involving, for example, the importance of consistency, the role of rationality, the degree of generalizability associated with a conception, and what can or can not be known are important to the learners experience and may need to be addressed during instruction.

Teachers with strong backgrounds in historically important issues to the development of science concepts, philosophical issues in science, an understanding of theoretical components identified in the CCM, and pedagogical strategies that are useful in addressing conceptual learning are in a position to facilitate conceptual change learning for their students. These requirements obviously place added burdens on the teacher. However they are indicative not of how a teacher would "do" conceptual change instruction but of what a teacher needs to think about while students are engaged in instruction intended to address conceptual understanding. Hewson and Hewson (1988, pp. 607-608) identified the following pedagogical practices necessary for teachers considering using principles of conceptual change in their instruction:

- be able to diagnose their students' thoughts on the topic in hand, e.g., by using a pretest based on prior research, by posing a question which will elicit students' responses, etc.

- make provisions for students to be able to clarify their own thoughts, through individual work or in group discussions, generally guided by well-planned questioning. In terms of the conceptual change model, students come to understand the basis on which their conception is plausible, and perhaps fruitful, to them.
- ensure that there be a direct contrast between students' views and the desired view, either by the teacher presenting the desired view or by it emerging from the class. In terms of the conceptual change model, students have to become dissatisfied with their existing ideas.
- provide immediate opportunities for the desired view to be used in explaining a phenomena. This might be achieved with carefully planned questioning, perhaps around a demonstration or after a laboratory session. This provides an opportunity for the students to see that the desired view is a plausible one.
- provide immediate opportunity for students to apply their newly acquired understanding to different examples, both closely and more distantly related to the original example. This helps students see that their new conception is fruitful.

These practices are useful in thinking about the delivery of conceptual change instruction and are consistent with what the teacher must have thought about prior to instruction – the role played by status and conceptual ecology components of the CCM, issues important to the historical development of the science concept, and significant philosophical issues related to how a particular science concept is known to be valid.

Thoughts About Learners

Finally, the success of conceptual change instruction rests squarely on two closely related issues, both under the control of the learner. First, the ability of a learner to reflect on their own thinking, to be metacognitive, is an implicit assumption running throughout this paper. Metacognitive abilities on the part of a learner are necessary when determining the status of a conception, after observing events or demonstrations that

initiate dissatisfaction, when assessing an idea in opposition to your own thoughts, when deterring what is anomalous and why – in short, whenever learners' thoughts require examination of the status of an idea or any component of the conceptual ecology. Teachers need to help students establish a language that is sufficiently detailed and useful in describing their thoughts. Hennessey's (1991) students did this by defining and using the status language of the CCM (i.e., intelligible, plausible, and fruitful). Although it is not absolutely necessary for students to use the language of the CCM, it is necessary that teachers are able to distinguish between conceptions that are intelligible and those that are intelligible and plausible. The initial plausibility of a competing conception is a necessary precursor to conceptual change (Strike & Posner, 1992). Second, motivating learners' to engage in any part of conceptual change instruction (Pintrich, Marx, & Boyle, 1993) as well as in acts involving metacognition (White & Gunstone, 1989) is not easily accomplished. However, successful conceptual change instruction is associated with classrooms in which students accepted their role as learners to include: a) the focus of instruction is explicitly on their ideas rather than the correct scientific conception alone, b) classrooms in which the learners ability to think about their ideas is a focus of instruction (i.e., the learners' ideas drive the curriculum), and c) instructional activities related to establishing metacognitive abilities on the part of the learner are as important a part of the instruction as are well done demonstrations used to illustrate discrepant events (Beeth, 1993).

Conclusion

Successfully implementing principles of conceptual change during science instruction should not be taken as a given. The role of a teacher attempting to teach for conceptual change includes assessing the status of students' conceptions at any point in time, identifying components within a student's conceptual ecology that might need to be addressed during instruction, knowledge of significant issues in the development of a science concept,

and the ability to engage students in metacognitive activities necessary for conceptual change to occur. Engaging students in activities designed to elicit metacognitive reflection is of paramount importance to conceptual change instruction and deserves attention from the science education research community.

Teaching for conceptual change also places new roles and responsibilities on the teacher, learner, and the curriculum. Teachers need new and different kinds of knowledge about the nature of science, the development of science concepts, and how students ideas can be made part of instruction. Students need to accept their roles as active constructors of knowledge. Accepting this role is not assumed to be easy nor is it well understood. Teacher's and students both have added responsibilities in creating and maintaining a learning environment devoted to conceptual change instruction. In terms of the curriculum, it is necessary to determine what issues in science are worth addressing through conceptual change and when to implement principles of conceptual change instruction into a teacher's practice. It is not assumed that the use of conceptual change instruction is appropriate to all science learning. Each of these roles represents a significant departure from more traditional roles - from one of the teacher imparting science content knowledge in it's final form to one of active construction and continual (re)evaluation of what a learner knows about a scientific concept and how a community of individuals' justifies their understanding of that concept.

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